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(54) **High performance powdered metal mixtures for shaped charge liners**

(57) A liner (18) for a shaped charge (10) that utilizes a high performance powdered metal mixture to achieve improved penetration depths during the perforation of a wellbore. The high performance powdered metal mixture includes powdered tungsten and powdered metal binder. The powdered metal binder may be selected from the group consisting of tantalum, molybdenum, lead, copper and combination thereof. This mixture is compressively formed into a substantially conically shaped liner (18).

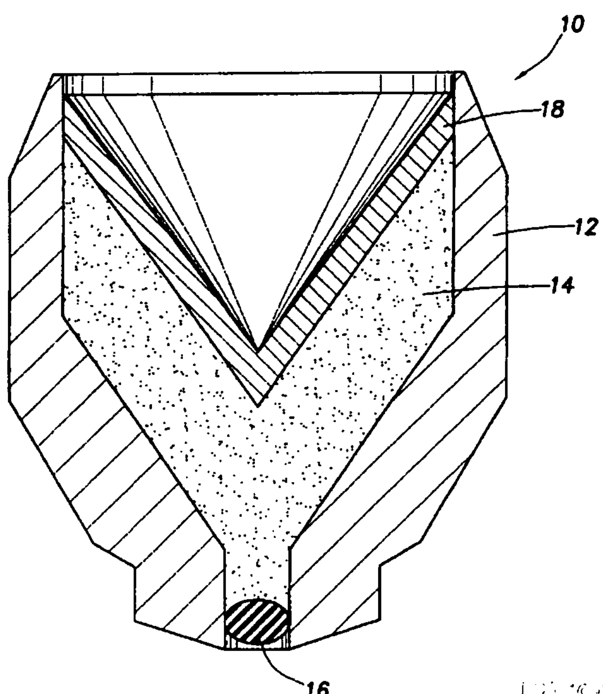

FIG. 1

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Description

[0001] The present invention relates in general to explosive shaped charges and, in particular to, high performance powdered metal mixtures for use as the liner in a shaped charge used, for example, in oil well perforating.

[0002] The background of the invention will be described, by way of example, with reference to perforating oil wells to allow for hydrocarbon production. Shaped charges are typically used to make hydraulic communication passages, called perforations, in a wellbore drilled into the earth. The perforations are needed as casing is typically cemented in place with the wellbore. The cemented casing hydraulically isolates the various formations penetrated by the wellbore.

[0003] Shaped charges typically include a housing, a quantity of high explosive and a liner. The liner has a generally conical shape and is formed by compacting powdered metal. The major constituent of the powdered metal was typically copper. The powdered copper was typically mixed with a fractional amount of lead, for example twenty percent by weight, and trace amount of graphite as a lubricant and oil to reduce oxidation.

[0004] In operation, the perforation is made by detonating the high explosive which causes the liner to collapse. The collapsed liner or jet is then ejected from the shaped charge at very high velocity. The jet is able to penetrate the casing, the cement and the formation, thereby forming the perforations.

[0005] The penetration depth of the perforation into the formation is highly dependent upon the design of the shaped charge. For example, the penetration depth may be increased by increasing the quantity of high explosive which is detonated. It has been found, however, that increasing the quantity of explosive not only increase penetration depth but may also increase the amount of collateral damage to the wellbore and to equipment used to transport the shaped charge to depth.

[0006] Attempts have been made to design a liner using a powdered metal having a higher density than copper. For example, attempts have been made to design a liner using a mixture of powdered tungsten, powdered copper and powdered lead. This mixture yields a higher penetration depth than typical copper-lead liners. Typical percentages of such a mixture might be 55% tungsten, 30% copper and 15% lead. It has been found, however, the even greater penetration depths beyond that of the tungsten-copper-lead mixture are desirable.

[0007] Therefore a need has arisen for a shaped charge that yields improved penetration depths when used for perforating a wellbore. A need has also arisen for such a shaped charge having a liner that utilizes a high performance powdered metal mixture to achieve improved penetration depths.

[0008] The present invention disclosed herein comprises a liner for a shaped charge that utilizes a high performance powdered metal mixture to achieve improved penetration depths during the perforation of a wellbore. The high performance powdered metal mixture includes powdered tungsten and powdered metal binder including one or more high performance materials. The powdered metal binder may be selected from the group consisting of tantalum, molybdenum, lead, copper and combination thereof. This mixture is compressively formed into a substantially conically shaped liner. The mixture may additionally include graphite intermixed with the powdered tungsten and powdered metal binder to act as a lubricant. Alternatively or in addition to the graphite, an oil may intermixed with the powdered tungsten and powdered metal binder to decrease oxidation of the powdered metal.

[0009] The use of high performance materials such as tantalum and molybdenum as the major components of the binder optimizes the performance of a shaped charge as these high performance materials have not only a high density, but also, a high sound speed. It has been determined that the density of the powdered metal in the shaped charge liner has a very significant effect on penetration depth, a higher value being more desirable. Rather than simply increasing the density of the powdered metal mixture, it is also important to maintain a relatively high sound speed of the mixture to achieved better shaped charge performance.

[0010] In one embodiment of the present invention, the liner mixture has approximately 70 to 99 percent by weight of tungsten and approximately 1 to 30 percent by weight of either tantalum or molybdenum or a combination of tantalum and molybdenum. Alternatively, lead may be substituted weight for weight with up to 20 percent of the tungsten. Alternatively or additionally, copper may be substituted weight for weight for a portion of either the tantalum or the molybdenum.

[0011] In another embodiment of the present invention, the liner mixture has approximately 50 to 90 percent by weight tungsten and approximately 10 to 50 percent by weight of the powder metal binder. The powdered metal binder may have approximately 0 to 20 percent by weight lead and 1 to 30 percent by weight tantalum or molybdenum. Alternatively, the powdered metal binder may have approximately 0 to 20 percent by weight lead, 1 to 30 percent by weight tantalum and 1 to 30 percent by weight molybdenum. As another alternative, the powdered metal binder may have approximately 0 to 20 percent by weight lead, 1 to 30 percent by weight tantalum or molybdenum and 1 to 30 percent by weight copper. Each of the embodiments of liner mixtures may be incorporated into a shaped charge of the present invention.

[0012] Reference is now made to the accompanying drawing, Figure 1, which is a schematic illustration of an embodiment of a shaped charge having a liner according to the present invention.

[0013] Referring to figure 1, a shaped charge according to the present invention is depicted and generally designated

10. Shaped charge 10 has a generally cylindrically shaped housing 12. Housing 12 may be formed from steel or other suitable material. A quantity of high explosive powder 14 is disposed within housing 12. High explosive powder 14 may be selected from many that are known in the art for use in shaped charges such as the following which are sold under trade designations HMX, HNS, RDX, HNIW and TNAZ. In the illustrated embodiment, high explosive powder 14 is detonated using a detonating wave or shock provided by a detonating cord 16. A booster explosive (not shown) may be used between detonating cord 16 and high explosive powder 14 to efficiently transfer the detonating wave or shock from detonating cord 16 to high explosive powder 14.

[0014] A liner 18 is also disposed within housing 12 such that high explosive 14 substantially fills the volume between housing 12 and liner 18. Liner 18 of the present invention is formed by pressing, under very high pressure, powdered metal mixture. Following the pressing process, liner 18 becomes a generally conically shaped rigid body that behaves substantially as a solid mass.

[0015] In operation, when high explosive powder 14 is detonated using detonating cord 16, the force of the detonation collapses liner 18 causing liner 18 to be ejected from housing 12 in the form of a jet traveling at very high velocity toward, for example, a well casing. The jet penetrates the well casing, the cement and the formation, thereby forming the perforations.

[0016] The production rate of fluids through such perforations is determined by the diameter of the perforations and the penetration depth of the perforations. The production rate increases as either the diameter or the penetration depth of the perforations increase. The penetration depth of the perforations is dependant upon, among other things, the material properties of liner 18. It has been determined that penetration depth is not only dependant upon the density of the powdered metal mixture of liner 18 but also upon the sound speed the powdered metal mixture of liner 18.

Table 1

Element	Density (g/cc)	Sound Speed (km/sec)	Acoustic Impedance
Tungsten	19.22	4.03	77.45
Copper	8.93	3.94	35.18
Lead	11.35	2.05	23.27
Tin	7.29	2.61	19.03
Tantalum	16.65	3.41	56.78
Molybdenum	10.21	5.12	52.28

[0017] Table 1 lists the density, the sound speed and the acoustic impedance of several metals which may be used in the fabrication of liner 18 of the present invention. In theory, liner 18 could be made from 100% tungsten as this would yield the highest acoustic impedance for the powdered metal mixture of liner 18. Manufacturing difficulties, however, prevent this from being practical. Because tungsten particles are so hard they do not readily deform, particle-against-particle, to produce a liner with structural integrity. In other words, a liner made from 100% tungsten will crumble easily and is too fragile for use in shaped charge 10. Attempts have been made to combine tungsten and a malleable binder material such as lead or tin. As can be seen from table 1, these materials, have low sound speeds which may result in poor jet tip formation. Thus, the resulting penetration depth of a liner made from a combination of tungsten and either a lead or tin is not optimum.

[0018] Liner 18 of the present invention, replaces some or all of the lead or tin with one or more high performance materials such as tantalum or molybdenum. These high performance materials typically have both a high density and a high sound speed as well as suitable malleability which gives strength to liner 18.

[0019] The powdered metal mixture of liner 18 of the present invention comprises a mixture of powdered tungsten and one or more of the high performance materials. For example, the powdered metal mixture of liner 18 of the present invention may comprises a tungsten-tantalum mixture, a tungsten-molybdenum mixture, a tungsten-tantalum-molybdenum mixture, a tungsten-tantalum-lead mixture, a tungsten-molybdenum-lead mixture, a tungsten-tantalum-molybdenum-lead mixture, a tungsten-tantalum-copper mixture, a tungsten-molybdenum-copper mixture, a tungsten-tantalum-molybdenum-copper mixture, a tungsten-tantalum-lead-copper mixture, a tungsten-molybdenum-lead-copper mixture or a tungsten-tantalum-molybdenum-lead-copper mixture. In each of the above mixtures, the tungsten is typically in the range of approximately 50 to 99 percent by weight. The tantalum is typically in the range of approximately 1 to 30 percent by weight. The molybdenum is typically in the range of approximately 1 to 30 percent by weight. The copper is typically in the range of approximately 1 to 30 percent by weight. The lead is typically in the range of approximately 0 to 20 percent by weight. The powdered metal mixture of liner 18 may additionally include graphite to act as a lubricant. Alternatively or in addition to the graphite, an oil may mixed into the powdered metal mixture to decrease

oxidation of the powdered metal.

[0020] More specifically, liner 18 of the present invention may contain approximately 50 to 90 percent by weight of tungsten, approximately 0 to 20 percent by weight of the lead, approximately 1 to 30 percent by weight of the tantalum and approximately 1 to 30 percent by weight of the molybdenum. Alternatively, liner 18 of the present invention may contain approximately 50 to 90 percent by weight of tungsten, approximately 0 to 20 percent by weight of the lead, approximately 1 to 30 percent by weight of the tantalum and approximately 1 to 30 percent by weight of the copper. As another alternative, liner 18 of the present invention may contain approximately 50 to 90 percent by weight of tungsten, approximately 0 to 20 percent by weight of the lead, approximately 1 to 30 percent by weight of the molybdenum and approximately 1 to 30 percent by weight of the copper. Liner 18 of the present invention may alternatively contain approximately 50 to 90 percent by weight of tungsten, approximately 0 to 20 percent by weight of the lead and approximately 1 to 30 percent by weight of the tantalum. Likewise, liner 18 of the present invention may contain approximately 50 to 90 percent by weight of tungsten, approximately 0 to 20 percent by weight of the lead and approximately 1 to 30 percent by weight of the molybdenum.

[0021] Using the mixtures of the present invention for liner 18, the penetration depth of shaped charge 10 is improved, compared with the penetration depths achieved by shaped charges having liners of compositions known in the art. The follow results were obtained testing various powdered metal mixtures for liner 18 of shaped charge 10 of the present invention.

Table 2

Mixture (Component Weight %)	Penetration Depth/in (mm)
55%W - 27%Ta - 18%Pb	8.24 (209)
55%W - 45%Ta	6.11(155)
55%W - 20%Cu - 15%Pb - 10%Ta	8.72 (221)
55%W - 20%Cu - 15%Pb - 10%Ta	7.64 (194)
55%W - 20%Cu - 15%Pb - 10%Ta	7.74 (197)

[0022] All of the embodiments described above contain tungsten in combination with a high performance material to provide liner 18 with increased penetration depth when the jet is formed following detonation of shaped charge 10. As explained above, use of tungsten alone to form liner 18 would result in a very brittle and unworkable liner. Therefore, tungsten is combined with other materials to give the tungsten based liner the required malleability. The present invention achieves this result without sacrificing the performance of shaped charge 10 by combining the powdered tungsten with high performance materials such as tantalum and molybdenum. In addition, these mixtures may also contain copper, lead or both.

[0023] Various modifications and combinations of the illustrative embodiments as well as other embodiments of the invention, will be apparent to persons skilled.

Claims

1. A liner (18) for a shaped charge (10) comprising: a mixture of powdered tungsten and powdered metal binder including approximately 50 to 90 percent by weight of the tungsten and approximately 10 to 50 percent by weight of the binder, the binder being selected from the group consisting of lead, copper, tantalum, molybdenum and combinations thereof, the mixture being compressively formed into a substantially conically shaped rigid body.

2. A liner (18) according to claim 1, wherein the binder further comprises: approximately 0 to 20 percent by weight of the lead; and approximately 1 to 30 percent by weight of the tantalum and/or approximately 1 to 30 percent by weight of the molybdenum.

3. A liner (18) according to claim 2, wherein the binder further comprises approximately 1 to 30 percent by weight of the copper.

4. A liner (18) for a shaped charge comprising: a mixture of powdered tungsten and powdered metal binder including approximately 70 to 99 percent by weight of the tungsten and approximately 1 to 30 percent by weight of the binder, the binder comprising tantalum or molybdenum, and the mixture being compressively formed into a substantially conically shaped rigid body.

5. A liner (18) according to claim 4, further comprising lead in substitution of the tungsten weight for weight wherein the lead forms a fractional weight of the mixture within a range of approximately 0 to 20 percent.

6. A liner (18) according to claim 4 or 5, wherein the binder further comprises copper and/or molybdenum.

7. A liner (18) according to any preceding claim, further comprising powdered graphite intermixed with said tungsten and said powdered metal binder to act as a lubricant.

8. A liner (18) according to any preceding claim, further comprising oil intermixed with said tungsten and said powdered metal binder to decrease oxidation.

9. A shaped charge (10) comprising: a housing (12); a quantity of high explosive (14) inserted into the housing (12); and a liner (18) according to any preceding claim inserted into the housing (12) so that the high explosive is positioned between the liner (18) and the housing (12).

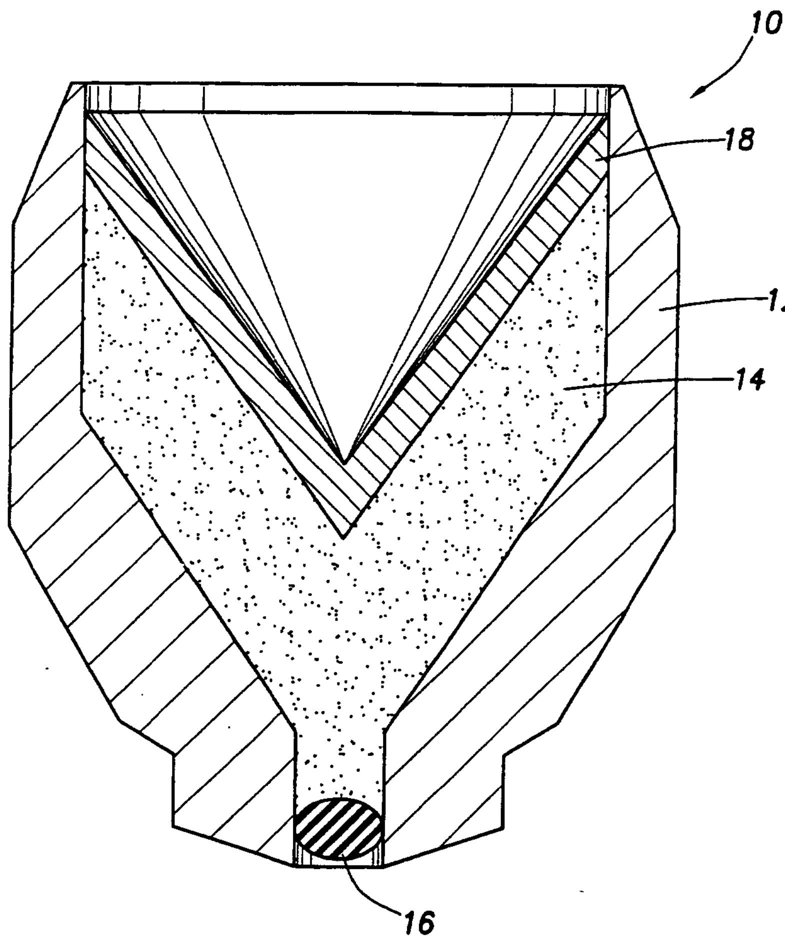

FIG. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 01 30 1015

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	3 July 2001	Alvazzi Delfrate, M

CATEGORY OF CITED DOCUMENTS

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